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Research Article

Sexual Dimorphism on the Sacrum of the Dog: A Morphometric Study

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A B S T R A C T

In this study, 59 adult canine sacrums, comprised of 30 male and 29 female, with 23 different breeds were used. A total of 5 osteometric measurements were taken from each of the sacrums and a total of 3 sacrum index indices were calculated using these measurements. Statistically significant differences were observed between the mean values of osteometric measurements in males and females (P<0.05). However, it was determined that the difference between the mean values of the index values of males and females was not statistically significant. Hence, although linear measurements are important in terms of revealing the difference in sexual size in dimorphism, it was concluded that it would be useful to reveal different indices to make different index calculations, especially in cases where sacrum width is foregrounded.

Keywords: Dog, morphometry, sacrum, sexual dimorphism

Köpek Sacrumunda Seksüel Dimorfizm: Bir Morfometrik Çalışma

Ö Z E T

Bu çalışmada 23 farklı ırktan 30 erkek ve 29 dişi olmak üzere 59 yetişkin köpek sacrum'u kullanıldı. Her bir sacrum'dan toplam 5 adet osteometrik ölçüm alındı ve bu ölçümler kullanılarak toplam 3 farklı sacrum indeksi hesaplandı. Dişi ve erkeklerde osteometrik ölçümlerin ortalama değerleri arasında istatistiksel olarak anlamlı farklılıklar gözlendi (P<0,05). Ancak dişi ve erkeklerin indeks değerlerinin ortalama değerleri arasındaki farkın istatistiksel olarak anlamlı olmadığı belirlendi. Dolayısıyla doğrusal ölçümler dimorfizmde cinsiyete bağlı büyüklük farkını ortaya koymak açısından önemli olsa da özellikle sacrum genişliğinin ön planda olduğu durumlarda farklı indeks hesaplamaları yapmak için farklı indeksleri uygulamanın faydalı olacağı kanaatine varılmıştır.

Anahtar Kelimeler: Köpek, morfometri, sacrum, seksüel dimorfizm

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Introduction

Dogs have different sizes and visual morphologies, and skull shape is mentioned as the most important criterion in determining standard dog breeds (Onar et al., 2001) Therefore, the current skull typology has been widely used in the differentiation and identification of morphological types (Stockard, 1941; Komeyli, 1984; Brehm et al., 1985; Regedon et al., 1991; Onar, 1999; Onar et al., 2001). Another important factor affecting visual morphology are sexual differences. Sexual dimorphism refers to differences in size and form between males and females (Nganvongpanit et al., 2017). Therefore, determining the gender is considered as a first step in the creation of the biological profile (Yadav et al., 2015). Gender identification through bone morphology in dogs is quite limited (Nganvongpanit et al., 2017). Definitions have been generally made on the pelvic bones (Onodera et al., 1987; Sajjarengpong et al., 2003; Cariier, 2005; Nganvongpanit et al., 2017). It has been reported that sexual dimorphism between males and females can be revealed by using the equations created by pelvic morphometry (Nganvongpanit et al., 2017), and it would be useful to know the pelvis morphometry to identify genetic variations in postcranial morphology (Carrier, 2005). In addition to the use of pelvis morphometry in sexual dimorphism in dogs (Onodera et al., 1987; Sajjarengpong et al., 2003; Carrier, 2005; Nganvongpanit et al., 2017), there is no information about a sexual dimorphism related only to the sacrum similar to observed in humans. With the shape and morphometry, the sacrum has been the most commonly used bone, especially in humans (Ravalia and Wagh, 2015; Yadav et al., 2015; Ahankari and Ambali, 2016; Bajpai and Maiyyar, 2016;). In dogs, the assessments of this bone have been at a very limited level only in the pelvis studies (Onodera et al., 1987; Sajjarengpong et al., 2003; Carrier 2005; Nganvongpanit et al., 2017). As being a component of the pelvis, it is a fact that this bone is effective to define sexual dimorphism similar to that in humans (Ravalia and Wagh, 2015; Yadav et al. 2015; Ahankari and Ambali, 2016; Bajpai and Maiyyar, 2016).

Sacrum in dogs has occurred through the constitution of three vertebrae (Evans and Christensen, 1979; Bahadır and Yıldız, 2010). This bone, which looks like a square when viewed from the dorsum (Bahadır and Yıldız, 2010), is firmly attached through the articulatio sacroiliaca to the os ilium bones of the ossa coxae (Dyce et al., 1987). This joint plays an important role in carrying body weight and transferring propulsion from the pelvic limbs to the spine (Gregory et al., 1986; Knaus et al., 2003). The sacrum, an unpaired bone, which participates in the formation of this joint, has been considered a mechanical necessity along with the task of this joint (Çalışlar, 1995). From biomechanical point of view, the pelvic limbs musculature is responsible for kinetic energy generation, which must be transmitted to the body trunk without loss (Çalışlar, 1995). This bone participates in the formation of the pelvis (Çalışlar, 1995; Dursun, 2007; Bahadır and Yıldız, 2010; Ahankari and Ambali, 2016). Thus, it forms the dorsal boundary so-called "birth canal", which is bounded laterally by the ossa coxae (Bahadır and Yıldız, 2010).

The sacrum, which is a dorsal component of the pelvis, is affected by all functional pressures on the pelvis (carrying weight, birth, and mode of locomotion) together with the pelvis from, and contributes to revealing the sexual size difference together with the pelvis (Csanády et al., 2019).

In this study, the relationship between sacrum morphometry and sexual dimorphism was investigated in dog breeds with different typologies and sizes. For this aim, it was evaluated whether there was a sexual dimorphism based only on the sacrum, as similar to that in humans (Ravalia and Wagh, 2015; Yadav et al., 2015 Ahankari and Ambali, 2016; Bajpai ve Maiyyar, 2016).

Material and Method

A total of 59 adult canine sacrums, including 30 males and 29 females, from a heterogeneous population (with 23 different sizes and skull types) were used in this study, (Table 1). Sacrums were derived from the existing collections of Istanbul University-Cerrahpaşa, Osteoarchaeology Practice and Research Centre, and the required ethics committee permission was obtained (Permission from İÜC, Faculty of Vet. Med. dated 24.03.2021 and numbered 60696).

Sacrum osteometric measurements were evaluated by using a digital calliper according to the criteria by von den Driesch (1976).

A total of 5 osteometric measurements of the sacrum (Fig. 1) were taken in this study. A total of 3 sacrum indices were calculated using these measurements.

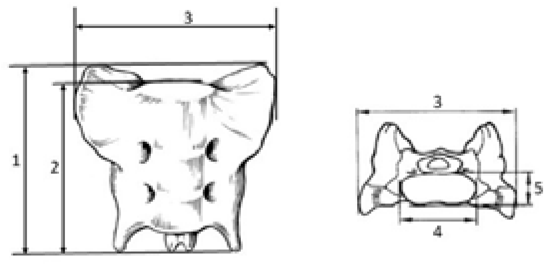

Figure 1. Sacrum osteometric measurements (from von den Driesch 1976)

Sacrum measurements: (from von den Driesch, 1976)

S1-Greatest length on the ventral side: from the cranial borders of the wings to the caudoventral border of the body of the last vertebra.

S2-Physiological length, measured between the centres of the bodies of the first and the third vertebrae.

S3-Greatest breadth (between the wings od sacrum)

S4-Greatest breadth of the facies articularis cranialis

S5-Greatest height of the facies articularis cranialis

Table 1. Dog breeds and gender distribution

Dog breeds	Male	Female
Kangal	2	2
Malaklı	2	0
St. Bernard	2	1
German Shepherd	6	4
Bernese Mountain	1	0
Rottweiler	4	1
Golden Retriever	0	2
Pointer	1	1
Shar-Pei	0	1
Doberman	2	1
Irish Setter	0	1
English Setter	0	2
Canaan Dog	1	0
Pitbull	0	1
Boxer	2	2
English Bulldog	2	0
French Bulldog	0	1
Pekingese	1	0
Chow Chow	0	2
Pomeranian	1	0
Cocker Spaniel	1	1
Dachshund	0	2
Terrier	2	4
Total	30	29

Sacrum indices:

Index-1=S3 (Greatest breadth)*100/S1 (Greatest length on the ventral side)

Index-2=S3 (Greatest breadth)*100/S2 (Physiological length)

Index-3=S5 (Greatest height of the facies articularis cranialis)*100/S1 (Greatest length on the ventral side)

The statistical analyses of the taken measurements and calculated indices were performed by SPSS 21.0 program (Version 21.0, SPSS Inc., Chicago, IL, USA). After calculating the mean and standard deviation values in males and females, the Shapiro-Wilk test was used to control for a normal distribution of the measurements. The Independent-Samples T test was applied to check the significance of the difference between the mean values of both genders that the data were normally distributed. The obtained statistical data are presented in tables, and the writing of the study is based on Nomina Anatomica Veterinaria (2017).

Results

In this study, the sacrums of the dog breeds from heterogeneous population (different sizes and skull types) were used. The sacrums were composed of 3 vertebrae, there was no fusion of the 1st caudal vertebrae. The osteometric measurements of these sacrums are presented in Table 2.

The osteometric measurements of the male dogs showed a higher value compared to female dogs. Taking into account of the usage of the heterogenous dogs with different sizes and types, these values had a fairly higher standard deviation except for the height (S5) of the Facies articularis cranialis.

Statistically significant differences were observed between the mean values of osteometric measurements in males and females ($P<0.05$). Although heterogenous dog breeds with different size and types were used, the osteometric values of the sacrum had a higher value in males. The differences of the mean values between males and females indicated the sexual size difference.

Three index calculations were performed using sacrum osteometric measurements (Table 3). Among these index calculations, the indices numbered 1 and 2 were calculated based on the width of the sacrum, and the index numbered 3 was calculated based on the height of the sacrum. The difference between the mean values of

Table 2. Sacrum osteometric measurements (mm)

Sex	Statistical	S1	S2	S3	S4	S5
MALE						
(n=30)	Mean	46.01	42.52	55.94	28.62	13.80
	SD	12.05	11.10	13.49	6.61	3.25
	Minimum	20.01	18.48	26.40	13.92	6.06
	Maximum	68.48	65.17	77.01	38.84	17.98
FEMALE						
(n=29)	Mean	40.04	36.93	48.70	25.47	12.17
	SD	8.72	7.85	9.94	4.97	2.71
	Minimum	25.83	24.05	31.50	14.40	7.40
	Maximum	54.68	52.00	66.07	34.55	17.39
	P	0.034	0.030	0.023	0.043	0.042

Table 3. Indices

Sex	Statistical	Index-1	Index-2	Index-3
MALE (n=30)	Mean	122.63	132.61	30.25
	SD	12.91	12.97	3.18
	Minimum	98.42	103.42	23.51
	Maximum	153.21	162.09	37.56
FEMALE (n=29)	Mean	123.18	133.36	30.56
	SD	17.46	19.03	3.65
	Minimum	99.47	108.45	22.73
	Maximum	181.37	202.79	41.87
	P	0.891	0.859	0.731

the index values in males and females was not statistically significant.

Discussion

As a component of the pelvis, the sacrum plays an important role in transferring the driving force from the pelvic limbs to the spine at the junction of the pelvic limb and spine (Gregory et al., 1986; Knaus et al., 2004). Therefore, it functionally effects pelvis (Kumar et al., 2018). Sacrum has been the most widely used bone in terms of sexual dimorphism, along with its shape and morphometry (Ravalia and Wagh 2015; Yadav et al., 2015; Ahankari and Ambali, 2016; Bajpai and Maiyyar, 2016; Joshi and Puranik, 2016), especially in revealing the biological profile in humans (Yadav et al., 2015). The assessments of this bone in dogs have been evaluated only at a very restricted level only in studies related to the pelvis (Onodera et al., 1987; Sajjarengpong et al., 2003; Cariier, 2005; Nganvongpanit et al., 2017). For this reason, sacrum morphometry and indices have been commonly used (Ahankari and Ambali, 2016; Bajpai and Maiyyar, 2016; Joshi and Puranik, 2016). With this aim, varying indices have been produced by these researches. With these assessments, it has been concluded that a single index cannot define the sex of sacrum with 100% accuracy, and therefore, it has been indicated that more than one index should be used to define the sex through the sacrum with 100% accuracy (Joshi and Puranik, 2016; Yadav et al., 2015). In this study, assessments were basically performed through the 3 indices. Indices numbered 1 and 2 were calculated based on the width of the sacrum, and the index number 3 was calculated based on the height of the sacrum. However, it was found that all three indices were not sufficient to reveal the sexual dimorphism.

In this study, the largest value among linear measurements was found in sacrum width as similar to those indicated by Ocal et al. (2006). This showed that in heterogeneous dog populations, even with different breeds, the width of the sacrum had a very large value compared to the length. Especially in male individuals, this linear measurement value was calculated remarkably high. The difference with females was statistically significant in terms of sexual dimorphism.

Sexual dimorphism refers to differences in size and form between male and female individuals (Nganvongpanit et al., 2017). For this reason, while it carries an important role in terms of bioarchaeology and forensic sciences in the sex identification of human skeletons (Nganvongpanit et al., 2017), it also provides great benefits in predicting the visual morphological characters of animals, and determining sex in zooarchaeological studies (Carey 1982; Grigson 1982a, 1982b; Greenfield, 2002). In the scope of the information given, it was particularly aimed to contribute to zooarchaeological studies in the present study. Although not directly, it would contribute to the importance of size differences in sex estimation based on sacrum morphometry.

Sexual size difference occurs in the sacrum because it is simultaneously affected by all functional pressures on the pelvis (carrying weight, birth, and mode of locomotion) (Csanády et al., 2019). However, calculated indices in this study were not statistically significant for the size difference. Although the effect of birth activity on the dimorphism of sacrum size has been known (Csanády et al., 2019), it was concluded that the unknown birth activities of the female dogs included in the present study were effective in evaluating the effects on the indices. The direct effect of linear measurements can be observed.

It has been known that anatomical differences are seen among dog breeds depending on the locomotion and activity form the limbs and pelvis (Schutz et al., 2009; Carlon and Hubbard, 2012). For example, in dogs with different morphological types and activities, such as Greyhounds and American Pit Bull terriers, it has been suggested that having thin or thick limbs and strong shaping of the pelvic muscles depending on locomotor anatomy cause structural anatomical differences on the pelvis, apart from sexual differences (Chase et al., 2002; Schutz et al., 2009). In this study, it is expected that 23 different dog breeds show anatomical differences in pelvis and limbs depending on their locomotion and activity. Presumably, these differences have the same effect on the sacrum, which is a component of the pelvis.

Therefore, it is thought that it may be useful to perform the evaluation of the statistical differences in linear measurements in terms of indices through grouping the different morphological types.

Conclusion

As a result, while a sexual dimorphism was observed on direct linear measurements in sacrum morphometry, sacrum indices calculated using these measurements were not statistically significant. Although linear measurements are important in terms of revealing the difference in sexual size in dimorphism, it was concluded that it would be useful to present different indices, especially to make different index calculations with sacrum width in the foreground. Nonetheless, it is believed that it would be useful to consider the sacrum indices by grouping the different morphological types of dog breeds.

Conflict of interest

The authors declare that they have no conflict of interest in this study.

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